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A Wolfram in Sheep's Clothing: Economic Warfare in Spain, 1940–1944

LEONARD CARUANA AND HUGH ROCKOFF

During World War II the United States attempted to prevent Germany from acquiring wolfram (tungsten ore) in Spain by buying it in the open market. Preemptive buying forced the Germans to pay more for and to consume less tungsten, a material crucial for the production of machine tools and armor-piercing shells. The income provided an important incentive for Spain to remain neutral. The naval blockade and the relatively low elasticity of the supply of wolfram contributed to the success of the wolfram-buying campaign.

Increasingly in recent years, the United States has used economic sanctions as means of statecraft. These measures have been used not because of confidence in their effectiveness, but rather because the alternatives, military force and diplomatic persuasion, are often so unattractive.[1] The United States is willing to use military force, as it has in the Persian Gulf, Kosovo, and most recently Afghanistan, but only after the provocation passes a high threshold. Attempts at persuasion are always possible, but may be ineffective in the absence of a credible threat or incentive. There is an extensive literature about sanctions and incentives—including important work by Gary Clyde Hufbauer, Jeffrey Schott, and Kimberly Ann Elliott; Klaus Knorr; Harry R. Strack; David Baldwin; and many others—exploring individual cases and deriving generalizations about the determinants of success.[2] Nevertheless, it is fair to say that the study of sanctions is still in a formative stage. The study of sanctions and incentives has been undertaken from a variety of viewpoints, ranging from game theory to diplomatic history. We believe, as we try to

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[1] Elliott and Hufbauer, "Same Song."

[2] Hufbauer, Schott, and Elliott, *Economic Sanctions*; Knorr, *Power*; Strack, *Sanctions*; and Baldwin, *Economic Statecraft*.

show in this article, that economic historians also have a role to play in defining the potentials and the limits of economic warfare.

One of the most complex and important uses of economic warfare by the United States occurred in Spain during World War II. A long list of measures were employed by the Allies: oil embargos, offers of loans, blacklisting of firms that dealt with the Axis, and even the buying of strategic materials to keep them out of enemy hands. The most important of the strategic materials purchased in Spain was wolfram, the source of tungsten, a metal crucial in the making of armor, armor-piercing shells, machine tools, and other war-related items. Most of these methods of economic warfare have been used in recent years. The policy of preemptive buying of strategic materials, for example, has its contemporary counterpart in efforts to buy Russian nuclear materials and to hire Russian laboratories and scientists formerly engaged in research on biological warfare.

Aspects of the economic war have been examined by a number of able historians: David L. Gordon and Royden Dangerfield, Herbert Feis, James Cortada, Paul Preston, and Christian Leitz, to cite merely some of the leading treatments in English.[3] These studies have clarified the impact of the economic war in Spain and the relationship between developments in Spain and the larger war aims of the Allies and the Axis. Here we use new data from the Spanish archives on wolfram production to resolve what we believe to be one of the important remaining questions: how effective was the attempt to preempt the Germans in the market for Spanish wolfram?

THE FIRST OIL EMBARGO.

The fall of France created a crisis in relations between Spain and Britain. It seemed probable that Francisco Franco, Spain's right-wing dictator, would bring Spain into the war on the side of Germany—"The Great Temptation," as Spanish historians know the episode. On 12 June 1940 Franco declared that Spain was no longer neutral; Spain was merely "nonbelligerent." This was the language that Mussolini had used before joining the war. On 14 June 1940 Spanish troops occupied the international city of Tangier on the African side of the straits of Gibraltar, the most aggressive military action taken by Spain during the war. A Spanish delegation, moreover, began negotiating with the Germans over the terms of Spanish entrance into the war. It seemed to many Spanish military officers that the war would soon be over, and that Spain had to move fast to join the winning side. Franco may well have believed that this was a unique opportunity to expand Spain's empire in Africa.

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[3] Gordon and Dangerfield, *Hidden Weapon*; Feis, *Spanish Story*: Cortada, *United States*; Preston, *France*; and Leitz, "Nazi Germany's Struggle," *Economic Relations*, and "More Carrot."

The strategic threat to Britain posed by Spain's entry was clear. If the Axis captured Gibraltar and fortified the corresponding coast of North Africa, the British fleet would have no way of challenging the powerful Italian fleet. Hitler, we now know, was then in the process of developing plans, code-named Felix, to take Gibraltar.[4] To prevent Spain from joining the war, the Allies began an embargo of shipments of oil to Spain on 27 July 1940. Embargoes, as a rule, have a bad reputation. The embargo of aviation fuel and other strategic materials to Japan imposed on 26 June 1940, for example, which hardened into a total oil embargo over the next year, failed to achieve its objectives. But the Spanish embargo is an important counterexample. The embargo played havoc with the Spanish economy because Spain had almost no oil reserves. Spain's only refinery, moreover, was in the Canary Islands, so even the crude oil awaiting processing was not available. The possibility that a substantial part of the fishing fleet would not put to sea was a dire threat for a country that was already hungry. To offset the embargo, and as a reward for joining the war, Spain asked Germany for 400,000 tons of gasoline and 200,000 tons of fuel oil, along with 600,000 tons of wheat, 200,000 tons of coal, and substantial quantities of other raw materials, including cotton, rubber, wood pulp, hemp, and jute.[5] When the Germans failed to supply Spain, Spain was forced to treat with Britain and the United States, and an agreement was reached quickly on 7 September 1940. Spain would receive oil and other supplies as long as she remained strictly neutral and submitted to detailed monitoring of her use of oil and other resources. Thus, in little more than three months after Spain declared her nonbelligerency and occupied Tangier, the oil embargo had pushed Spain into the neutral corner.

As shown by Jonathan Eaton and Maxim Engers, embargoes arise because of misperceptions on one side or both about the costs of embargoes.[6] In our case, the embargo arose because the Franco regime did not recognize a major problem that the Germans already faced and that Spain would face if it joined the Axis: limited supplies of raw materials. The correction of a Spanish misperception—that Germany was so well endowed with resources that she could easily make good shortfalls produced by an Allied embargo —seems to us the best explanation for the success of the embargo.[7]

Hitler's interest in Spanish entry grew during 1940, and he decided to talk directly to Franco. They met at Hendaye, in France on the Spanish border, on 23 October 1940—their only face-to-face meeting. On the military side, Hitler wanted Franco's help in capturing Gibraltar and the cession of land for permanent bases in the Canary Islands and Morocco. And he wanted to keep the final division of French Morocco secret—to calm fears in Vichy France, to discourage French forces in Morocco from joining the Free French, and to encourage the Italians who also dreamed of an expanded African empire. Franco wanted firm guarantees for Gibraltar and all of French Morocco, and he did not want to cede the bases that Germany demanded. On the economic side, Hitler wanted substantial mining concessions, whereas Franco provided a long list of raw materials he wanted as a precondition for going to war, especially oil and food.

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[4] Burdick, *Germany's Military Strategy*.

[5] Preston, *Franco*, p. 372.

[6] Eaton and Engers, "Sanctions."

[7] The best-known use of economic sanctions during the 1930s was the failed attempt by the League of Nations to force Italy to withdraw from Ethiopia. Ristuccia, "1935 Sanctions," however, argues convincingly that if the sanctions had included an oil embargo, even one that kept U.S. sales to Italy at their peacetime level, they would have had a good chance of being successful. On the structure of the Italian sanctions and their effects, all see Curovic, *Essays*.

We cannot know which gap, the military or the economic, was the more important to Franco. Indeed, interpretations of the meeting at Hendaye have multiplied to Roshomon-like proportions.[8] Most historians, although they recognize the economic considerations, tend to see the territorial considerations as most important. But our view is that the potential scarcity of raw materials, brought to the fore by the oil embargo, has an equally plausible claim to being the decisive factor. Spanish officials had learned at first hand how costly a scarcity of oil would be. Supplies of wheat for a hungry Spain, moreover, were now on their way from Canada and the United States. How certain could Franco be that Germany would supply Spain with enough food if Spain joined the war?[9]

In 1940 and 1941 the decision to remain neutral merely appeared prudent; in hindsight, of course, the decision seems nothing less than brilliant. Had Spain joined the war, there was a real possibility that the Allies would have decided to fight their way into Europe through Spain rather than Italy. The losses for Spain under those circumstances would have been staggering. In Italy real GDP per capita fell 60.54 percent between 1939 and 1945, whereas in Spain real GDP per capita rose 8.38 percent. One might, perhaps, have expected an even larger increase in Spain because Spain was just beginning to recover from the disastrous effects of the Great Depression and Civil War.[10] But in any case, it is clear why many in Spain breathed a sigh of relief when Spain avoided Italy's fate.[11]

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[8] Preston, "Franco," presents his own take on the meeting and discusses the literature.

[9] In private correspondence Christian Leitz remained unconvinced that the embargo was the main factor. He would stress the ongoing refusal of Germany to agree to Franco's demands for territory in Africa.

[10] The Spanish experience appears to be in line with that of the other Western European neutrals. Real per capita income in Sweden rose 10.18 percent between 1939 and 1945, whereas in Switzerland it rose 19.79 percent. In Turkey, however, it fell 47.08 percent. All data are from Maddison, *Monitoring*, pp. 194–98. He does not provide data for Portugal. Maddision, ibid., pp. 69–71, discusses the wide variety of wartime experiences.

[11] The long-run effects of the war are harder to discern. The net capital stock in Italy actually increased slightly during the war, and her economy recovered and grew rapidly afterwards (Zamagni, "Italy," p. 179 and passim).

As a neutral, moreover, Spain was able to reap enormous profits from the sale of a commodity that had been little noticed in Spain before the war.

WOLFRAM

Spanish and Portuguese wolfram became an important raw material for the German war effort.[12] Tungsten has the highest melting point of any metal and is one of the hardest and heaviest. Steel alloyed with tungsten is extremely hard and heat resistant. In the war tungsten was used mainly in armor, armor-piercing shells, friction-resistant bearings, and high-speed cutting tools, although it had a number of other military uses including fireproofing materials and electrical contacts. The Germans were the first to develop shells with a core of tungsten carbide for piercing armor. These shells were a key to Rommel's early successes in North Africa. Two years later the United States was using similar shells to stop German tanks in the Battle of the Bulge.[13] The Germans were also among the leaders in the development of tungsten alloys for high-speed cutting tools that were important for sculpting artillery and other munitions.

To explore the market for wolfram we rely on two sources: annual data on the price and quantity of wolfram covering the years 1911–1955 published by the Banco Exterior, and quarterly data on price and quantity covering the years 1941–1944 that we built up from the reports of individual mines available in the Ministry of the Treasury reports.[14] The first source allows us to put the wolfram boom in long-term perspective; the second to see the effects of intrawar events and to test our conclusions against data that have been adjusted for changes in the quality of the ore being mined.[15]

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[12] At the time, "wolfram" often was used as a synonym for tungsten. (The chemical symbol for tungsten is W.) The term was also used, as we will used it here, as the name for tungsten-bearing ores. In Spain and Portugal the bulk of this ore was wolframite (also sometimes referred to as wolfram), a mineral that contains iron and manganese in combination with an oxide of tungsten. Small amounts of Scheelite, a mineral that contains calcium in combination with an oxide of tungsten, and a tin-bearing tungsten ore, were also mined. The origin of the term wolfram is obscure. It has been suggested that it derives from the frustrations experienced by the alchemists when they attempted to extract tin from minerals containing tin and tungsten—the tungsten acted like a wolf eating the tin. The word "tungsten" apparently derives from the Swedish for heavy stone.

[13] Li and Wang, *Tungsten*, p. 402.

[14] National Archive in History (Spain): Ministry of Treasury; contemporary funds, general series 11.701 to 11.711.

[15] The reason that mine-level data are available is that the Spanish government taxed wolfram at the mine level prior to the war at the rate of 3 percent of the total amount sold. Spain may also have been influenced by the Fascist idea that data should be collected on raw materials useful to the military. We have data by mine on output, quality of the ore, the price at which it was sold, and the total value of output, during the wolfram boom. Although the records appear to be complete for the years 1941–1943, there are some gaps in 1944. In additions, there may be some reporting errors due to tax evasion, which probably existed despite the government's reputation for ruthlessness, and also to recording errors made by relatively poor and uneducated miners. For this reason, we rely on mine-level data for information on prices, the quality of ore bing mined, and other variables that can be estimated from a sample, but

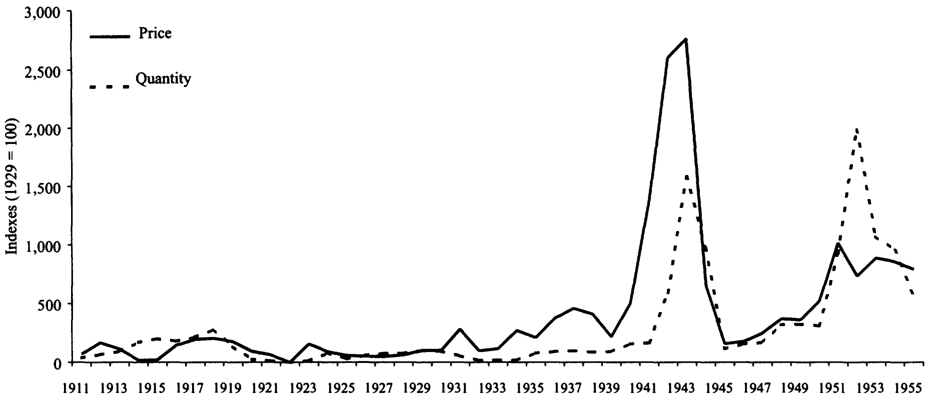

FIGURE 1
PRICE AND QUANTITY OF SPANISH WOLFRAM, 1911–1955

Source: See the text.

Annual indexes (1929 equals 100) of the real price of wolfram and quantity produced are plotted in Figure 1. The booms during World War I, World War II, and the Korean War stand out. As might be expected, output lagged behind prices during World War II, whereas the output response was quicker and more intense during the Korean War—the second time around. But clearly, the main things that need to be understood are the astonishing increases in prices and quantities during World War II.

The Demand for Wolfram

Before the war Germany bought wolfram mainly from China, the British colonies in Asia, and to a much lesser extent, Portugal and Spain. In 1938, probably the peak prewar year, Germany bought 14,200 metric tons, with only 658 tons coming from Portugal, and only 119 from Spain.[16] German demands for Iberian wolfram escalated rapidly once the war began. The naval blockade made it hard to bring in wolfram by sea, and an overland route to China was impossible after the attack on the Soviet Union. The only other European producer was Sweden, but Sweden's production barely covered domestic consumption. Thus, Spain and Portugal became the only places where Germany could obtain wolfram.

The idea of competing with the Germans for wolfram originated with the British; initially, the Americans were skeptical. The United States could easily buy wolfram from the rest of the world (Table 1), and the United

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on regional estimates of output published by the Banco Exterior for information on total output when we run the regressions.

[16] Leitz, *Economic Relations*, p. 173.

TABLE 1
WARTIME PRODUCTION OF TUNGSTEN ORE IN BRITISH LONG TONS

Country	1939	1940	1941	1942	1943	1944	1945
China	10,907	8,619	11,334	11,800	8,573	3,184	NA
United States	3,217	4,571	6,023	8,422	10,763	9,161	5,055
Bolivia	3,284	4,117	4,284	5,517	6,823	7,810	3,498
Burma	9,935	10,364	NA	1,852[a]	1,852[a]	1,852[a]	1,852[a]
Portugal[b]	3,370	3,096	6,863	4,599	6,555	4,118	NA
Spain[c]	225	386	408	1,488	3,974	2,436	284
Korea[d]	NA	NA	2,400	2,400	2,900	3,900	1,500
Japan	None	None	667	927	791	650	NA
Siam	341	NA	873	1,502	1,579	1,032	419
Total[e]	36,408	36,517	37,278	46,447	55,685	43,400	19,286

[a] Average annual production during Japanese occupation for the years 1942, 1943, 1944, and 1945.

[b] Smithells gives figures for several types of ore. We summed them after adjusting to a 65 percent tungstenic-oxide equivalent using Smithell's estimates of the average tungstenic-oxide content, to make the sums more comparable to the estimates for Spain.

[c] The figures for Portugal and Spain do not take into account the wartime decline in the quality of the ore.

[d] Estimated exports to Japan, 1941 to 1945.

[e] The total includes additional countries.

Notes: In addition to wolframamite, the main ore, this table includes small amounts of Scheelite, and concentrates of tin-bearing ore. The amount of tungsten in the ore varied somewhat from country to country and year-to-year, but generally the ore averaged about 56 percent tungstenic oxide, 44 percent pure tungsten. The British long ton is 2240 pounds; the metric ton is 2204.6 pounds.
Source: Smithells, *Tungsten*, pp. 10–11.

States had abundant supplies of molybdenum, a good substitute for producing hardened steels. According to Feis, Jesse Jones, the head of the Reconstruction Finance Corporation (the agency that would be the conduit for American finance), thought the idea of preemptive buying was "silly."[17]

Why, then, did the United States agree to preemptive buying shortly after entering the war? Why not simply tell Franco that if he did not cut all shipments of wolfram to Germany, reductions in oil, wheat, and other supplies would be made? After all, the first oil embargo had been successful. To some extent the oil weapon was used. The price of oil was raised, and the flow was diminished in response to particular political situations. Eventually, a second oil embargo was imposed to try to force a complete cut off in Spain's exports of wolfram to Germany. But for several reasons the Allies decided to rely on preemptive buying during most of 1942 and 1943. First, the Allies were afraid that if they pressed too hard they might yet drive Spain into the Axis. And the British were concerned about damaging long-term relations with the Franco regime. Second, the structure of the industry (much of it was a highly competitive "cottage industry") meant that it was

[17] Feis, *Spanish Story*, p. 169. Jones was happy, however, to buy wolfram for the U.S. stockpile. In June 1940 he financed the acquisition of Chinese wolfram stored in Indo-China (Li and Wang, *Tungsten*, p. xiv).

extremely difficult to monitor compliance, even if the Spanish government agreed to prohibit exports to Germany. A third reason lay in the structure of the U.S. bureaucracy. The Bureau of Economic Warfare oversaw preemptive buying. This agency, initially headed by Henry Wallace, was only loosely controlled by the State Department and was conducting campaigns to buy other strategic materials in other parts of the world. It was natural for the bureau to attack the problem of wolfram through preemptive buying. As it turned out, the oil weapon was directed more toward political developments (the main concern of the State Department), whereas preemptive buying was used to deal with wolfram.

By the time the United States agreed to preemptive buying, the Portuguese situation had been resolved, at least temporarily. On 24 January 1942 the Germans signed an agreement with António Salazar, the Portuguese dictator, which assured the Germans a share of Portuguese wolfram. According to the agreement foreign countries that owned mines in Portugal (mainly Britain, although Germany owned a few) would be entitled to the wolfram produced in their mines. "Free wolfram," wolfram produced by Portuguese owned mines, was to be split. Initially, the Portuguese allocated 75 percent of the free wolfram to Germany, to make up for their lack of mines. In principle the initial split made 2,800 tons per year available to Germany. In return Germany promised to export 60,000 tons of steel and fertilizers to Portugal. Later, under Allied pressure, the split for the free wolfram was changed to 50:50, leaving the Allies with a much larger share of Portuguese production. Salazar created a Portuguese Metals Commission, which in principle became the sole buyer of wolfram, to fix the price of wolfram and control the trade.[18]

For much of the war, Portugal insisted successfully on its right to sell wolfram to Germany. Eventually, however, the threat of an oil embargo forced the Salazar regime to cut off sales to Germany, but not until the Allied invasion of Europe began. Overall, the Allies secured the larger share of Portuguese exports. The best available figures show that the Germans got 5 percent (185 tons) of Portuguese exports in 1940, 35 percent (1,814 tons) in 1941, 46 percent (2,169 tons) in 1942, 20 percent (1,342 tons) in 1943, and 26 percent (701 tons) in 1944.[19]

Although in principle all exports went through the Portuguese Metals Commission, there was an extensive black market. At times there was considerable smuggling from Portugal to Spain, an activity in which the Allies, as well as the Germans were heavily involved. William Medlicott estimates that 818 tons were smuggled across the Portuguese-Spanish border between

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[18] Kemler, *Struggle*, p. 63.

[19] We are extremely grateful to Joao Paulo Avelas Nunes who supplied these estimates to us. These figures probably miss some of the wolfram smuggled into Germany through Spain.

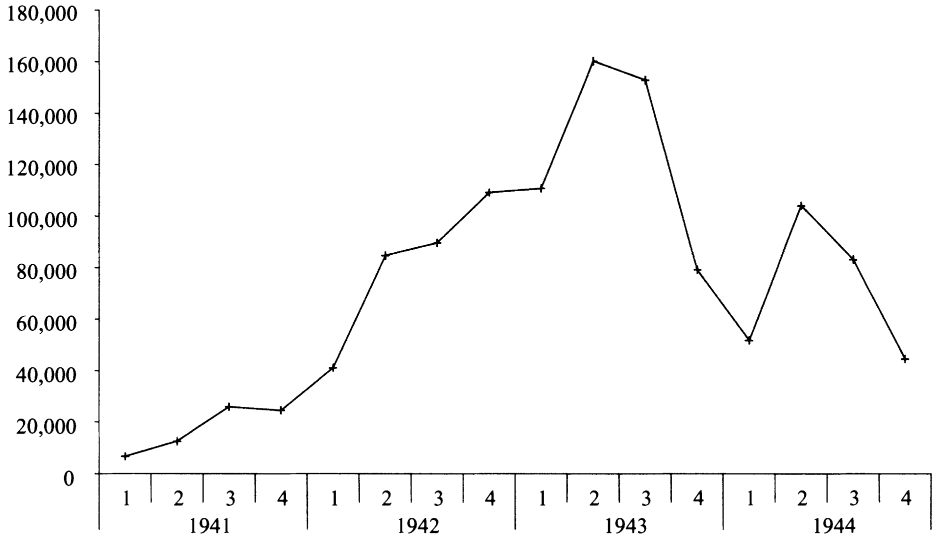

FIGURE 2
PRICE OF WOLFRAM IN SPAIN, 1941–1944
(1941 pesetas per metric ton of 0.65-equivalent ore)

Source: See the text.

January and August 1943.[20] The Germans purchased 550 tons and the Allies 268 tons. The flow reversed, as might have been expected, when prices dropped in Spain in late 1943. Smuggling appears to have continued until the Germans were driven from the Spanish frontier.

While the Portuguese supply was regulated with a heavy (although not always effective) hand, the Spanish industry was allowed to go its own highly competitive way. The Franco government taxed the industry, and required licenses to move wolfram domestically or export it, but otherwise left it alone. Allowing the industry to develop competitively proved to be of enormous benefit to Spain and the Franco regime. Once the United States was firmly on board the wolfram-buying program in the first quarter of 1942 prices in Spain increased from 12,500 pesetas ($1,141) in the second quarter of 1941, to 160,000 ($14,612) in the second quarter of 1943, a factor of close to 13 (see Figure 2).[21] Output increased from 159 tons in the second

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[20] Medlicott, *Economic Blockade*, p. 596.

[21] We calculated the price by dividing the total value of ore produced in all reporting mines (probably all mines through most of the period) by total tungstenic-oxide content of the ore (the sum over all mines of each mine's output multiplied by the tungstenic-oxide content of its ore), and multiplying the result by 0.65. We then deflated by the cost-of-living index set to 100 in the first quarter of 1941. Each mine also reported a price. In a number of cases price times quantity differed from total value, possibly because of recording errors, and possibly because the price represented a modal price, or something similar. The weighted average of these prices, however, is quite similar to the price that we use. There are prices for individual months scattered through the literature. In particular Leitz, *Economic Relations*, p. 181, cites a number of prices for individual months. In fact, these prices generally agree quite

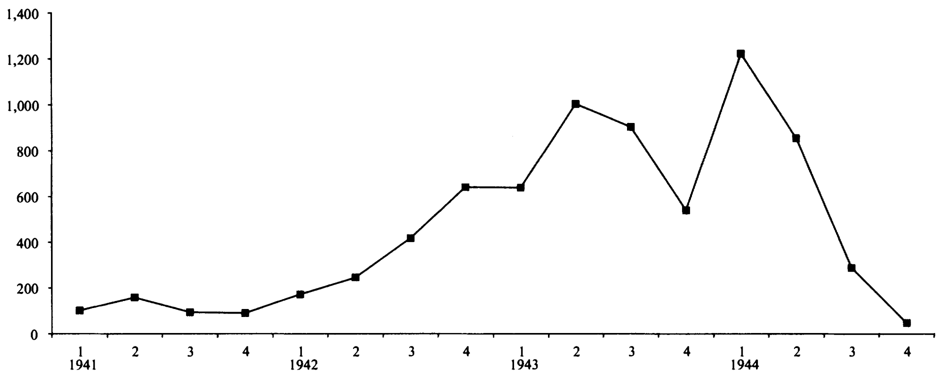

FIGURE 3
QUANTITY OF WOLFRAM, 1941–1944
(metric tons of 0.65-equivalent wolfram)

Source:

quarter of 1941 to a high of 1,223 tons in the first quarter of 1944 (see Figure 3).

The competition for wolfram was organized in a simple way. The British purchased wolfram through the United Kingdom Commercial Company; the Germans through their company, Sofindus; and the United States through the United States Commercial Company, modeled after its British counterpart. Paying for wolfram was not easy, even for the Allies. They taxed exports to Spain, especially oil and fertilizers. They also allowed Spain to accumulate restricted dollar balances in U.S. banks, and shipped gold. The Germans had an even harder time. Occasionally they resorted to looted and counterfeited foreign bank notes. They also shipped gold. Later, as we discuss in what follows, they raised pesetas by shipping arms and by canceling a substantial part of Spain's Civil War debt.

On the Spanish side there were two main figures: Serrano Suñer, from the Ministry of Foreign Affairs (appointed in September 1940), and Demetrio Carceller from the Ministry of Commerce (appointed in October 1940). Suñer, a Falangist, strongly favored the Axis. In an article in the Falangist newspaper *Arriba* he argued that Spain had to join the Axis in its war against the communists and the liberal democracies.[22] On the other hand, Carceller, although also a Falangist, tried to persuade the Allies to ignore

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closely with ours (they are generally with 1 or 2 percent) once allowance is made for the export tax. (Our prices are pretax.) This is somewhat surprising because our prices are from a completely different source. The one exception is late in 1944. The value in our series is $7,691 for the third quarter of 1944 and $4,922 for the fourth quarter. Leitz gives $1, 826 for September 1944. The sample by this point is small, and some mines are reporting very low prices and sales, similar to Leitz's figure. The official exchange rate, at which foreign governments bought pesetas, was 10.95 pesetas per dollar. There was also an active black market in Tangier. The black-market rate was considerably higher: 1941, 21.49 pesetas per dollar; 1942, 14.99; 1943, 13.25; and 1944, 15.21, Martín Aceña, *Estadistica históricas*, p. 391.

[22] *Arriba*, 15 August 1940, p. 42.

Suñer. On occasion Spain may have benefited from this nice-guy-tough-guy routine. Nevertheless, negotiations were disrupted in the early years of the war by Suñer's ideologically based opposition to the Allies. When Count Francisco Jordana replaced Suñer on 3 September 1942, relations with the Allies improved. From then on Spain's focus was on making sure that adequate supplies of oil, rubber, and food were forthcoming in exchange for wolfram.

The price of wolfram did not follow a smooth upward path. In May 1942 the price was so high that the Germans decided not to buy. In response the Spanish government refused to license German stocks for export. The Germans reconsidered, and began buying again in June. The hesitation in prices between the second quarter of 1942 and the third quarter reflects this contretemps (see Figure 2). On 7 January 1943 Spain announced an increase in the export tax from $5,000 per ton to 15,000 per ton. Both sides protested, and managed to scale the tax back to $10,000 per ton.[23] It may seem strange that the Allies protested a tax that reduced German consumption. It could be that the Allies had simply slipped into a commercial way of thinking inappropriate to the task at hand. It is also possible that the Allies were distinguishing among beneficiaries of Allied purchases. One of the great advantages of the wolfram-buying program, from the Allied point of view, was that much of the money went into the hands of small-scale producers. It was one thing for the Allies to put money into the pockets of poor Spanish miners; a very different thing to put money into the pockets of the Franco regime. The Allies may also have been afraid that Spain would secretly rebate the German portion of the tax. The Allies, of course, could avoid an export tax simply by warehousing their wolfram in Spain. But on 29 April 1943, in a change in the law that has been somewhat neglected, the tax was made applicable to all wolfram, whether exported or not.

Wolfram prices peaked in the second quarter of 1943, fell slightly, and then tumbled between the third quarter and the fourth quarter of 1943 (see Figure 2). The production tax may have had some effect. But the main reason was simply that the Germans had run out of pesetas. In response, the Allies abandoned the market as well.[24] Spain, however, came up with a clever ploy to keep the game going. The Franco regime owed Germany a large debt incurred during the Spanish Civil War. The Germans agreed to cancel the debt in exchange for a peseta balance that they could use to purchase wolfram. The Germans also promised and delivered military equipment. These weapons were valuable to Germany, and are an indication of how important Germany considered wolfram. The value of the Civil War debt, however, is debatable. If the Germans lost the war, they would have had a hard time collecting. A realistic market value of the Civil War debt must have been far below its nominal value. In effect, the Spaniards had found a way, with a veneer of legality, to price discriminate: a way to charge a lower price to the impecunious Germans and a higher price to the well-heeled Allies. Altogether the agreements made about 400 million pesetas available to the Germans, enough to buy and export close to 1,500 tons of wolfram at the prices prevailing in the third quarter of 1943. The rebounds in prices and production, shown in Figures 2 and 3, were the result of this deal.

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[23] Feis, *Spanish Story*, p. 221; and *Foreign Commerce Weekly*, vols. 9–10, 18–19.

[24] Abandoning the market may have been a mistake. Continued Allied purchasing would have prevented the Germans from buying wolfram at depressed prices when they returned to the market.

Although it is clear that the buying campaign raised the price of wolfram and discouraged German use, the extent to which it did so has remained a question mark. Among the Americans at the time there was considerable doubt about whether the enormous expense of the wolfram program was worth it; about whether the program was substantially reducing German consumption or, for the most part, simply stimulating production and enriching the Spaniards.

The Supply of Wolfram

The effect of the wolfram campaign depended on the elasticity of supply. At one extreme would be perfectly inelastic supply—a supply elasticity of zero. This would be the case that literally fulfilled Li and Wang's statement that "The Americans and British countered with preclusive purchasing on the theory that one pound of tungsten in the hands of the Allies in Portugal and Spain means one pound of tungsten less in the hands of Germany."[25] On the other hand, if the supply curve had been perfectly elastic—a supply elasticity of infinity—the Allied buying program would have had no effect on German consumption; each additional ton purchased by the Allies would have been met with an additional ton of Spanish production. At one point there were plans to purchase Spanish rabbit fur to preempt the Germans, who needed warm gloves for the eastern front. The plan was abandoned, however, when it was realized that the supply of rabbits indeed would be perfectly elastic! Intermediate elasticities would imply intermediate effects of Allied buying.

The increase in demand during the war was met mainly by expanding the number of small, high-cost producers. The industry was concentrated in Northwest Spain where small outcroppings of ore could be found. The miners were generally peasants, or farm workers.[26] The number of mines rose

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[25] Li and Wang, *Tungsten*, p. xv.

[26] Kemler, *Struggle*, provides a good physical description of the mining boom. Kemler served on the staff of the United States Commercial Company, and at the U.S. embassies in Lisbon and Madrid.

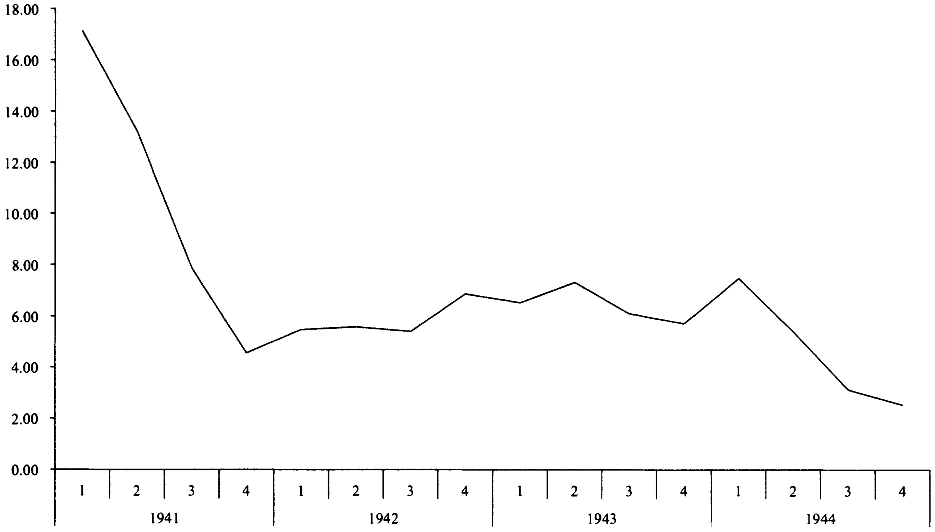

FIGURE 4
AVERAGE OUTPUT PER WOLFRAM MINE
(metric tons of 0.65-equivalent wolfram)

Source: See the text.

from six in the first quarter of 1941 to a maximum of 124 in the second quarter of 1943. Figure 4 plots the average output per mine, which plummeted as the small producers came in, eventually stabilizing at six or seven tons per mine. The new mines produced lower quality ore. This is shown in Figure 5, which plots the average percentage of Tungstenic Oxide (WO_3) in the ore. In general, producers in Germany and elsewhere were equipped to use ore that was about this quality; lower quality ores required additional processing. When the boom took hold, however, the quality of the ore dropped well below the 65 percent mark. Had the boom been expected to continue a long while, there would have been additional investment in mining, both private (exploration, machinery, training of workers, and so on) and public (improved highways or railroads in the mining regions), that would have shifted the short-run supply curve to the right. It is even conceivable that the long-run supply curve would have been downward sloping. The relatively large response in the Korean War compared with the response in World War II, may be evidence of a downward sloping long-run supply curve. But given the short-run nature of the boom, and the expectation that the boom would end with the war, there was little reason during World War II to make long-term investments beyond those that also served short-term purposes.

It is conceivable that, had the boom continued long enough, the available stock would have been depleted. The production in Spain during the Korean

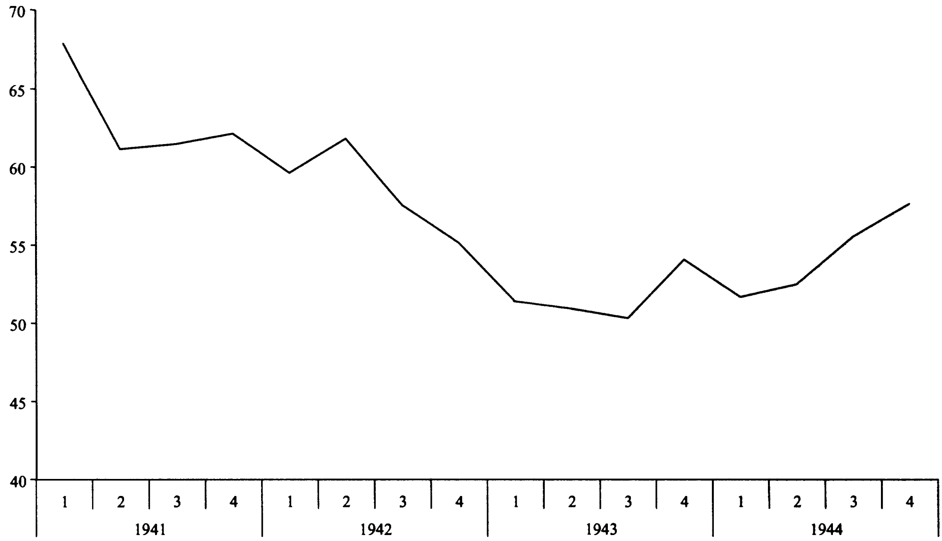

FIGURE 5
PERCENTAGE OF TUNGSTENIC OXIDE IN THE ORE

Source:

war, and the continued production during most of the postwar era (exports have fallen in recent years because of depressed prices), however, suggests that Spain was a long way from reaching the point at which depletion would have significantly affected costs in the 1940s.

As previously noted, demand fluctuated significantly, rising dramatically at first, collapsing when the Germans ran short of funds, rising again when the Spanish government made additional funds available to the Germans, and then collapsing when the land route to Germany was closed. The supply curve was relatively stable, with additional amounts being produced in small, normally unprofitable, mines. It would appear to be, therefore, the classic case in which a fluctuating demand curve identifies a stable upward-sloping supply curve. Perhaps the most convenient supply equation to fit, because the coefficients are easy to interpret, is the familiar constant-elasticity function.

$$Q = SP^{\alpha} \tag{1}$$

Or in logarithmic form

$$\log(Q) = \log(S) + \alpha\log(P) \tag{2}$$

where Q is the supply of wolfram, S is a shift term reflecting investment in the industry, P is the real price of wolfram, and α is the elasticity of supply.

TABLE 2
ESTIMATES OF THE SUPPLY FUNCTION FOR WOLFRAM

Sample	Annual, 1911–1955		Quarterly, 1941:1–1944:4	
Dependent Variable	Natural Logarithm of Wolfram Production	First Difference of the Natural Logarithm of Wolfram Production	Natural Logarithm of Wolfram Production	First Difference of the Natural Logarithm of Wolfram Production
Constant	1.91	0.03	–5.50	–0.13
	(1.59)	(0.19)	(–1.07)	(–0.73)
Real price of wolfram	0.71	0.62	1.00	0.64
	(3.45)	(2.82)	(2.20)	(1.66)
AR(1)	0.68		0.54	
	(5.94)		(1.82)	
Adjusted *R*-squared	0.67	0.14	0.56	0.11
Durbin-Watson	1.74	1.99	1.40	1.38

Notes: Absolute values of *t*-statistics are in parentheses.
Sources: See the text.

Representative results are shown in Table 2. The second column shows the results of regressing the natural logarithm of the annual output of Spanish wolfram on the natural logarithm of the real price lagged one period.[27] The resulting elasticity is 0.71. Although this regression passes the usual tests for autocorrelation, including the Durbin-Watson, which is shown in the table, experience shows that it is useful to estimate the equation in first differences as well. As usual the proportion of the first-difference variance explained is relatively small, but the supply elasticity, shown in column 3, is similar, 0.62. Estimating equation 2 with our quarterly data for the war years yields a supply elasticity of 1.00 when the equation is estimated in levels, and 0.64 when estimated in first differences.[28] We tried many alternative specifications to allow for more complicated adjustment patterns, and to attack the problem of serial correlation, but none produced estimates of the elasticity of supply far outside the range in Table 2. Evidently, the supply elasticity was relatively low in the short run, making wolfram a viable candidate for preemptive buying.

[27] In the annual sample, tests comparing a linear specification with the loglinear (the P_E test) showed that the linear specification is to be preferred. In the quarterly sample, there was no difference. The implicit elasticities from the linear equations (measured at the mean) and the measured shortfall in German consumption were similar to those computed from the loglinear equations. We discuss the loglinear equations in the text and report them in Table 2 mainly because it is convenient to have coefficients that are elasticities.

[28] A simple back-of-the-envelope estimate of the supply elasticity (α) for the war years would be the percentage change in output from 1939, when the boom began, to 1943, the peak annual production, (287 percent) divided by the percentage change in prices over the same period (254 percent), implying and elasticity of 1.13.

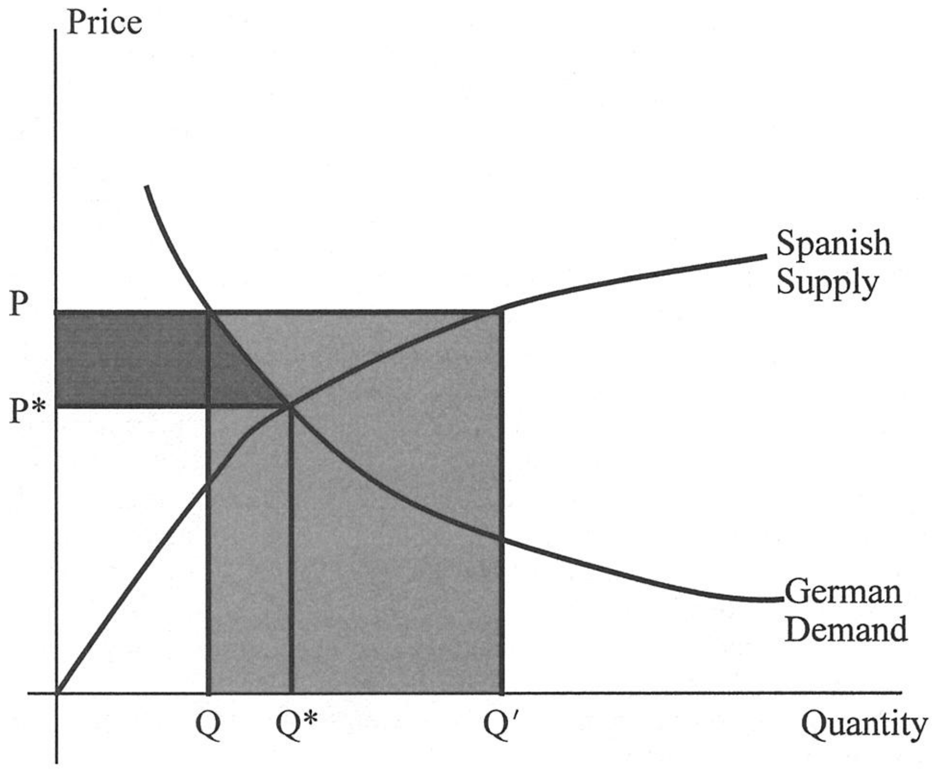

FIGURE 6
THE EFFECTS OF THE WOLFRAM-BUYING PROGRAM

Note: See the explanation in the text.

The Effects of the Wolfram Program

Figure 6 illustrates the effects of the wolfram-buying program. In the absence of the program the Germans would have bought Q^* tons at price P^*.[29] The Allies, however, entered the market pushing the price to P and production to Q', and forcing the Germans to move along their demand curve and reduce their consumption to Q. The German loss is the darkly shaded area. It consists of two parts: $(P - P^*) \times Q$, which is the additional amount Germany paid for the wolfram it actually bought, and the "triangle," $(1/2) \times (Q^* - Q) \times (P - P^*)$, which is the loss in consumer surplus on the wolfram it chose not to buy. The lightly shaded area $P \times (Q' - Q)$ is the

[29] This assumes a conventional demand curve. Although there were many consumers of tungsten in the German economy, it was possible for the German government to set overall price and quantity restrictions. So in the absence of allied competitors, the Germans could have acted as monopsonists, purchasing less wolfram but at a much-reduced cost. The Spaniards, in turn, might have countered, for example by setting a minimum price. When all was said and done, the result might not have been far different from the competitive solution assumed in the text. The model in the Appendix shows that similar functions and variables will remain crucial, even if we move to a game-theoretic approach.

gross cost of the program to the Allies. The net cost was less because the wolfram had some value, perhaps a value that would be realized after the war. But the "salvage" value could not have been much. The Allies could have procured the same amount of wolfram at a much lower cost after the war from other suppliers, if they had wished to do so. In fact, the wolfram they purchased in Spain was of so little value to them that they warehoused it.

Estimating these areas directly, however, produces numbers that are difficult to interpret. A more intuitive metric, because we can relate it to various aspects of the war effort, is the reduction in German consumption of wolfram ($Q^* - Q$). To estimate this amount requires an estimate of the elasticity of the German demand as well as of the Spanish supply. If we assume that Germany would have spent the same amount on wolfram in the absence of the Allied buying program as in the face of it (a demand elasticity of -1), we can derive the equation for the effect of the wolfram-buying program. Unit elasticity is a reasonable assumption because the Germans simply ran out of money in the third quarter of 1943 and stopped buying. To put it slightly differently, we are asking how much more wolfram the Germans could have bought if they had spent the same amount in Spain, but did not face competition from the Allies.

This assumption yields the following expression for the effect of the wolfram-buying program.[30]

$$Q^* - Q = -(Q' - Q)[\,1/(1 + \alpha)] \tag{3}$$

where $Q^* - Q$ equals the change in German consumption of wolfram produced by the Allied buying campaign, and $Q' - Q$ equals Allied purchases of wolfram.

This equation confirms the intuitive statements about the supply elasticity.[31] Allied purchases would reduce German consumption, but the effect would be small if the elasticity of supply was high. Table 3 shows estimates of the impact on German purchases based on notional supply elasticities that span the range shown in Table 2, and Leitz's estimates of German and Allied purchases.[32] Perfectly elastic supply and perfectly inelastic supply are shown by way of contrast. Perhaps our best estimate is the "bottom line."

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[30] We ignore the production tax. This equation would be strictly correct only if it were an ad valorem tax.

[31] In the more general case, when German demand is given by $Q_g = DP^{-\epsilon}$, equation 3 becomes

$$Q^* - Q = -(Q' - Q)\,[\epsilon/(\epsilon + \alpha)] \tag{4}$$

which reduces to equation 3 when ϵ equals 1. Equations 3 and 4 are derived by taking the time derivative of equation 1. Strictly speaking, they are only true for small displacements from an equilibrium in which Allied purchases are zero. The calculations in Table 4 are simulations based on equation 1.

[32] Leitz, *Economic Relations*, p. 176.

TABLE 3
THE EFFECT OF THE WOLFRAM-BUYING PROGRAM IN SPAIN ON GERMAN WOLFRAM CONSUMPTION, 1941–1944

Supply Elasticity	The Reduction in German Purchases of Wolfram Caused by Allied Buying (metric tons)	German Purchases in the Absence of Allied Buying [Counterfactual German Purchases] (metric tons)	Reduction in German Purchases Due to Allied Buying (percentage)[a]
Zero (perfectly inelastic supply)	–4,952	8,381	–89
Minimum estimate (0.50)	–2,793	6,222	–60
Median estimate (1.00)	–1,932	5,361	–45
Maximum estimate (1.50)	–1,474	4,903	–36
Infinite (perfectly elastic supply)	0	3,429	0
Median estimate of supply elasticity plus an adjustment for the cancellation of the civil war debt[b]	–1,511	4,940	–37

[a] The difference between the natural logarithm of the value shown in column 3 and the natural logarithm of actual consumption, multiplied by 100.
[b] See the text.
Note: If the reductions in German consumption are calculated separately for each year and summed, the results are similar.
Source: See text

It assumes the median supply elasticity and makes an adjustment for the cancellation of the Civil War debt—we simply assume that in the absence of the funds made available through the cancellation of the debt the Germans would have purchased only one-half of the wolfram they actually purchased after September 1943. All in all, then, it appears that the Allied buying program reduced German purchases of Spanish wolfram by a bit more than a third, by about 1,500 tons.

We believe that this amount justifies a claim of success by the Allies, at least in reaching the intermediate goal of reducing German purchases, if not the ultimate goal of reducing German war-making capacity. According to German figures, Germany used about 350 tons per month in 1939; compared with 160 tons per month in November 1943. Thus, in the absence of the Allied buying program in Spain, Germany could have increased consumption to the prewar level for about eight months without reducing expenditures in other directions.

Determining how important reaching this intermediate goal was to undermining the German war effort, however, is more difficult. After the war, German experts claimed that the quality of German hardened steel was maintained through the use of substitute alloys and production techniques.[33] Before the war German steel makers settled on an alloy containing about 13 percent tungsten, and smaller amounts of chromium, vanadium, cobalt, and carbon for use in high-speed tool steel. During the war they developed a substitute that contained about 4 percent tungsten, along with increased amounts of carbon, and an addition of molybdenum (2 to 3 percent). German metallurgists claimed that this alloy was superior to the prewar version.[34] German metallurgists also claimed that skillful quenching produced armor that was almost as hard as armor made from a tungsten alloy.

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[33] The United States Strategic Bombing Survey, *Effects*, pp. 109–12.

Nevertheless, there is evidence that the scarcity of tungsten damaged the German war effort. The most important use of tungsten on the battlefield was in tungsten-carbide cores for armor-piercing shells. The tungsten-carbide core increased the ability of the shell to pierce armor because it was harder and heavier than steel. At the beginning of World War II the Germans developed antitank guns with tapered barrels that fired shells with soft exteriors and tungsten-carbide cores. The tapered barrel squeezed the shot, producing extremely high muzzle velocities. These weapons did valuable work for Rommel in North Africa, and were probably the most effective antitank guns then in use. The scarcity of tungsten, however, forced the Germans to abandon this weapon.[35] The Germans apparently continued to produce some tungsten-carbide-cored ammunition for their tanks and antitank guns, perhaps for a short time, because these shells helped them cope with the heavily armored Russian tanks.[36] Even so, by the end of the war the growing scarcity of tungsten-cored shells had forced the Germans to limit each tank to, at most, a few rounds.[37]

The effectiveness of the tungsten-cored shell is shown by its adoption by the Allies. The Americans began developing tungsten-cored shells after some of the German antitank guns using this shell were captured in North Africa. Development was not pushed as rapidly as in retrospect it should have been because of the scarcity of tungsten and the belief that conventional guns and ammunition were sufficient. After D-Day, however, the army discovered that the Sherman Tank armed with its standard 75 mm gun, and firing conventional ammunition, was no match for the German Panther and Tiger tanks. Only shots fired at extremely close range, and hitting the more vulnerable tracking, could do any damage; the German tanks could destroy the Shermans at a distance. One palliative was to upgrade the

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[34] Li and Wang, *Tungsten*, p. 333.

[35] The weapon had other problems: the barrels wore out quickly, and the guns could not fire high-explosive shells. On the other hand, they were relatively light and easy to handle.

[36] Milward, *German Economy*, p. 105.

[37] The potential value of tungsten-cored shells can be seen in the penetration statistics. The famous German Tiger tank could penetrate 100 millimeters of armor plating (sloped 30°) at 1,000 meters when firing conventional armor-piercing shells; it could penetrate 174 millimeters when firing tungsten-cored shells. The front hull armor of the Joseph Stalin tank measured 120 millimeters at its thickest point. The Tigers carried (officially) about 90 rounds of ammunition, but only a few rounds of tungsten-cored shells–when available. Jentz, *Panzertruppen*, pp. 294–96.

Sherman to a 76.2mm gun and use a tungsten-cored shell.[38] Britain and the Soviet Union also developed tungsten-cored shells after encountering them.[39] Tungsten became a major component of Lend Lease to the Soviet Union.

Germany's desperate hunger for tungsten was revealed in the waning days of the war. One of the last Japanese submarines to make the run to Germany was sunk on 23 June 1944. Its cargo consisted of raw materials, the bulk being made up of tin, molybdenum, and wolfram.[40] The Germans, it was thought, also flew wolfram out of Spain on the last flights leaving Madrid. In any case, when the German embassy and consulates were searched at the end of the war, wolfram was found in the basements.[41]

Altogether it has been estimated that the Allies spent about $170 million purchasing wolfram in Spain and Portugal, including export fees, bribes, and so on, split about evenly between the United States and Britain. Measured against the contractual prices for U.S. weapons, this seems like a large sum. For example, the cost of a Sherman tank early in the war has been put at $35,000, suggesting that the Allies could have built another 4,860 tanks with the money spent on wolfram, increasing the number of Shermans by close to 10 percent. The contractual prices for weapons, however, do not reflect all the costs of increasing production. Significantly increasing the production of weapons would have meant equipping new factories and finding new supplies of labor both to produce weapons and to man them on the battlefield. Finding these resources would have incurred costs going far beyond the contractual price. As Michael Edelstein has shown recently, the constraints faced by U.S. production authorities in the early years of the war were real: more weapons contracts would have been counterproductive.[42] It is far from clear, moreover, that additional weapons, even if they could have been produced, would have been more effective at damaging the German military machine. Even if it had been possible, for example, to produce and man additional bombers, it is unlikely that increasing the intensity of bombing would have been a more effective use of resources. Attacks on nonferrous and ferro-alloy metal production facilities in Germany were not very effective.[43] Thus, it appears that preemptive buying was a clever way of using the superior financial resources of the Allies without aggravating the logjam in production, or the scarcity of trained personnel in the military. In 1944, the peak year, the U.S. federal government spent about $88.6 billion on the war. So the wolfram-buying programs added about 0.1 percent to the

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[38] Green, *Ordnance*, pp. 348–73.

[39] Hogg, *Tank Killing*, pp. 78–90.

[40] *New York Times*, 18 July 1995, p. C1.

[41] Leitz, *Economic Relations*, p. 194.

[42] Edelstein, "Size."

[43] The United States Strategic Bombing Survey, *Effects*, pp. 109–12.

TABLE 4
THE IMPORTANCE OF WOLFRAM FOR THE SPANISH ECONOMY, 1940–1944

Year	1940	1941	1942	1943	1944
Wolfram as a percentage of Spanish exports	0.37	0.69	7.68	19.81	27.22
Wolfram as a percentage of Spanish GDP	0.01	0.04	0.41	0.92	0.86

Notes: The numerator in each row includes only foreign exchange earnings; barter transactions, such as the German shipments of military equipment, are omitted. The denominator is adjusted to pounds using the market exchange rate from Tangier; the official peseta- pound rate was lower.
Sources: Exports; Leitz, *Economic Relations*, p. 172; GDP, Prados, "Spain's Gross Domestic Product"; and exchange rate, Martín Aceña, *Estadistica Histόricas*, p. 391.

total cost. Or to put it slightly differently, wolfram buying was the equivalent of about 8.5 hours of federal spending; 17 hours if the United States had shouldered the entire burden. Most Americans, we venture to say, would have been willing to work these additional hours on the chance that the war could be ended sooner.

There was one clear winner from the wolfram competition, where no counter-arguments are possible: Spain! Table 4 shows the impact of wolfram on Spanish exports. Wolfram grew from an insignificant 0.4 percent of Spanish exports in 1940 to over 25 percent in 1944. This was nearly one percent of Spanish national income. The export of wolfram is the most important exception to Tortella's generalization: "the Second World War was a lost opportunity for Spain to export many goods."[44] When it came to wolfram, Spain was dealt a good hand, and played it well.

THE SECOND OIL EMBARGO (22 JANUARY–2 MAY 1944)

Frustrated by the high price of wolfram and by the cancellation of the Civil War debt the Allies began debating a second oil embargo. Although wolfram was the key issue, "political" and military issues also played a role. These included: German spies in Spain, favorable treatment of Axis aircraft landing in Spain, the continuing presence of Spanish forces on the Eastern front,[45] and the stridently pro-Nazi propaganda in the Franco-controlled press. The U.S. State Department, responding to political pressure to get tough with Franco, and to the realization that American forces would soon be on the ground, wanted all wolfram exports to Germany cut off by D-Day, even if a total oil embargo had to be imposed. The British, more dependent on trade with Spain, and with long-term financial interests in Spain, wanted to continue the policy of preemptive buying, which in their view had worked well. But the British were willing, at least initially, to go along with the Americans.[46]

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[44] Tortella, *El Desarrollo*, p. 309.

[45] The famous Spanish Blue Division had been removed, but a smaller unit, the Blue legion, remained.

[46] Edwards, *Anglo-American Relations*, p. 4.

Spain was notified of the second oil embargo on 22 January 1944. The Spaniards bargained effectively. They announced a temporary ban on exports of wolfram to Germany while the dispute was resolved. Although some writers have speculated that this ban was turned into fact, it is now clear from evidence in the German archives that Spain continued to export wolfram to Germany during the oil embargo.[47] In February 104.6 tons were exported from Spain. There were no exports in March, and this may have reflected the ban. But in April 198 tons reached Germany from Spain.[48] Clearly, the Spanish government could not or would not comply.

Spain held out for a face-saving formula that would send token amounts to Germany. Spain pointed to its rights as a neutral under international law, and to the potential for Germany to use force against Spain in the form of air or submarine attacks. Spanish officials known to be sympathetic to the Allies argued that their position would be undermined if the Allies insisted on a complete ban. The division between the Allies increased as the negotiations dragged on. On 13 February 1944 Churchill cabled Roosevelt, and reiterated his opposition to the demand for a complete cutoff.[49] Roosevelt, however, remained convinced that an oil embargo would force Spain to cut off all exports of wolfram to Germany:

> "I believe that as a result of our suspension of tankers loading the Spanish situation is developing satisfactory and that if both our Governments (British and American) hold firm we can obtain a complete and permanent Spanish embargo on the export of wolfram to any country."[50]

On 30 March 1944 Churchill cabled again, pointing out in stronger language his reasons for reaching a quick compromise: the danger that Spain would smuggle wolfram to the Germans (there were thought to be between 700 and 1000 tons of wolfram stockpiled by the Germans in the Pyrenees) while negotiations continued, the potential loss to Great Britain of iron ore from Spain, 42 percent of Britain's supply, the loss of Spanish potash, which was essential for British agriculture, and the long-run loss of Spanish reliance on British finance. The struggle continued for another month, with Washington and London becoming increasingly vexed with each other. Washington argued that if the Allies remained firm, they could have a complete embargo; London argued that Spain would resist the humiliation of a total embargo, but would settle for a face-saving formula, with similar practical effects.

Finally, on 25 April, Churchill told Roosevelt that Britain was prepared to enter a separate agreement with Spain, and to supply her with oil.[51] This threat forced the United States to throw in the towel. The agreement ending the embargo was reached on 2 May. Spain would be allowed to export a maximum of 20 tons per month in May and June, and 40 tons per month thereafter. Smuggling undermined the agreement.[52] With the help of sympathetic Spanish officials the Germans managed to move about 512 tons to Germany in April through early July 1944 in addition to the 80 tons in May and June allowed under the May agreement. The promise to expel German agents from Spain was also evaded. In his memoir, the British ambassador complains that, two months after the May agreements 201 of 220 German agents on a list the British had given to the Spaniards were still at large.[53] Some political goals were met. The German Consulate in Tangier was closed (although the German agents remained on Spanish soil) and the press, which was controlled by the government, became less stridently pro-Axis, although this would have happened in any case, with the collapse of Germany. But on the whole, the second embargo, although carried out when the allied victory appeared all but inevitable, was a failure.

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[47] Feis, *Spanish Story*, pp. 255–61; and Leitz, *Economic Relations*, pp. 189–93.

[48] Leitz, *Economic Relations*, p. 189.

[49] Kimball, *Churchill and Roosevelt*, p. 726.

[50] Ibid., p. 728.

[51] Hayes, *Wartime Mission*, pp. 222–23.

When the Germans retreated from the Spanish border in August 1944, and it became impossible to ship wolfram to Germany by land, the demand for wolfram collapsed. The price of wolfram, as can be seen in Figure 1, tumbled to a level not seen since the German attack on the Soviet Union.

A CREATIVE RESPONSE

The economic war conducted by the Allies in Spain during World War II illustrates a wide range of means and outcomes. The first oil embargo, imposed when the Franco regime appeared to be moving rapidly toward entering the war, proved to be a considerable and (given the general record of embargos up to that time) unexpected success. The scarcity of oil played havoc with Spain's economy, and Germany was unable or unwilling to resupply Spain. As a result Franco learned what it would be like to be a full participant in the war, and this understanding was an important factor in his decision to keep Spain neutral. Preemptive buying of tungsten ore also proved to be a success. The impact of Allied buying depended, in the first instance, on the elasticity of Spanish supply. The evidence explored in this article shows that the elasticity of supply was in a range that made preemptive buying viable. Our best estimate is that the buying campaign reduced German purchases by about a third. Preemptive buying was costly, and its effectiveness was diminished by measures adopted in Germany to conserve tungsten. But alternatives, such as building more bombers and intensifying the bombing of German production facilities would also have been costly because of the production constraints in the United States and Britain, and probably of limited effectiveness.

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[52] Allied pressure also led to a ban on exports from Portugal on 6 June 1944. (The date is probably a coincidence.) The oil embargo in Spain served as a warning in the Portuguese negotiations; although a wide range of other pressures were brought to bear. See Sweeney, "Portuguese Embargo."

[53] Hoare, *Complacent Dictator*, p. 270.

For Spain, wolfram was a bonanza, adding, at the peak, almost 1 percent to GNP. The Spanish government, moreover, proved adept at milking the boom for all it was worth. When the Germans ran short of cash in August 1943, Spain accepted a cancellation of Spanish Civil War debts and military equipment in lieu of cash. In effect, Spain found a way to price discriminate—to charge a lower price to the impecunious Germans and a higher price to the well-heeled Allies.

An early imposition of a total oil embargo would not have worked better than preemptive buying to stem the flow of wolfram to Germany. The Second Oil Embargo imposed in January 1944 illustrates the weaknesses of a punitive regime. The embargo dragged on for three months while Spain haggled about terms and played the Americans, who were intent on forcing a total ban on exports of wolfram to Germany, against the British, who were willing to agree to a face-saving formula. An accord was reached when the British threatened to sign a separate agreement. The movement of wolfram was difficult to monitor during and after the negotiations because of the competitive nature of the industry, and smuggling continued until a land route to Germany was cut.

The Spanish-American Economic War, as we have styled it, illustrates the difficulty of forecasting the results to be expected from economic warfare because success is contingent on so many variables. In some circumstances, it appears, punitive measures were effective: witness the first oil embargo. But in other circumstances punitive measures were ineffective: witness the second oil embargo. Incentives, such as the buying campaign, a relatively neglected form of economic warfare, it turns out can be more effective, in the right circumstances, than embargos. Although mistakes were made, one must conclude that for the most part the Allies found their way successfully though the thicket of contingencies. In this economic war as in the conventional war, creative generalship made a difference.

Appendix: A Model of the Wolfram Conflict

The competition for wolfram can be put in a game theoretic framework that helps identify the key functions and variables. Define the following terms.

X_1 = quantity of wolfram purchased by the Allies

X_2 = quantity of wolfram purchased by Germany

$W(X)$ = supply function of X, the price that will induce Spain to sell a total of X units of wolfram, assumed to be a simple linear function of the total supply.

$D(X_1; X_2)$ = damage function representing the zero sum nature of military conflict. If $D(X_1; X_2) > 0$, then $D(X_1; X_2)$ is the damage imposed on the Allies by Germany; if $D(X_1; X_2)$

< 0 then $D(X_1; X_2)$ is the damage imposed on Germany by the Allies.

R_1 = the opportunity cost (in terms of damage imposed on Germany) for the Allies of using resources to buy wolfram rather than in some other way.

R_2 = the opportunity cost for Germany (in terms of damage imposed on the Allies) of using resources to buy wolfram rather than in some other way.

There are various plausible ways of framing this problem. Perhaps the most familiar is as a duopsony problem, in which the Allies and Germany choose their purchases independently and simultaneously. Suppose the damage function is given as follows

$$D(X_1; X_2) = b_2 X_2 - R_2 X_2 W(X_1 + X_2) - b_1 X_1 + R_1 X_1 W(X_1 + X_2) \qquad \text{(A1)}$$

In this setup b_1 and b_2 are the marginal effects of additional wolfram on the ability of the military to inflict damage on the enemy.

A pair $(X_1^*; X_2^*)$ is an equilibrium if

$$\begin{aligned} &X_1^* \text{ minimizes } D(X_1; X_2^*) \\ &X_2^* \text{ maximizes } D(X_1^*; X_2) \end{aligned} \qquad \text{(A2)}$$

Then for the right parameter values the solutions are as follows

$$\begin{aligned} X_1^* &= [2b_1R_2 + b_2(R_2 - R_1)] \,/\, W(R_1 + R_2)^2 \\ X_2^* &= [2b_2R_1 - b_1(R_2 - R_1)] \,/\, W(R_1 + R_2)^2 \end{aligned} \qquad \text{(A3)}$$

These results have some interesting properties that reinforce the interpretation in the text. Suppose that the wolfram is of no value to the Allies for military purposes ($b_1 = 0$) and that the opportunity cost of resources is the same for the Allies and for Germany ($R_2 = R_1$). Then the Allies will not enter the wolfram market ($X_1^* = 0$) and Germany will purchase the monopsonistic amount $[b_2 / (2R_2W)]$. But if the opportunity cost for the Allies is low compared with the cost for Germany, the Allies will enter the market, even if the wolfram is of no military value to them, reducing the amount purchased by the Germany: an economic war of attrition. For example, if ($b_1 = 0$), and if the opportunity cost for the Allies is one-third of opportunity cost for the Axis ($R_1 = 1/3R_2$), German purchases $[3/8(b_2 / R_2W)]$ will be only three-quarters of what they would have been under a German monopsony. The amount purchased by Germany, moreover, will fall as the slope of the supply function (W), which is related to the elasticity explored in the text, rises.

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